Electropolishing 1300 & 400 MHz SRF copper

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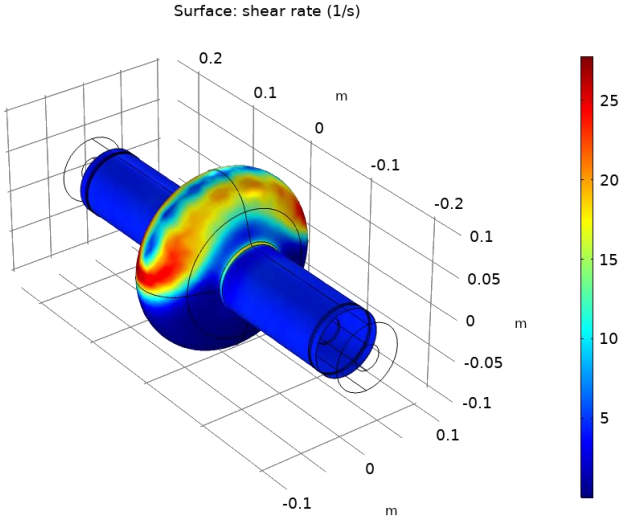
FCC Week 2022

31st of May 2022

Contents

- Electropolishing modelling and optimisation
- Experimental achievements

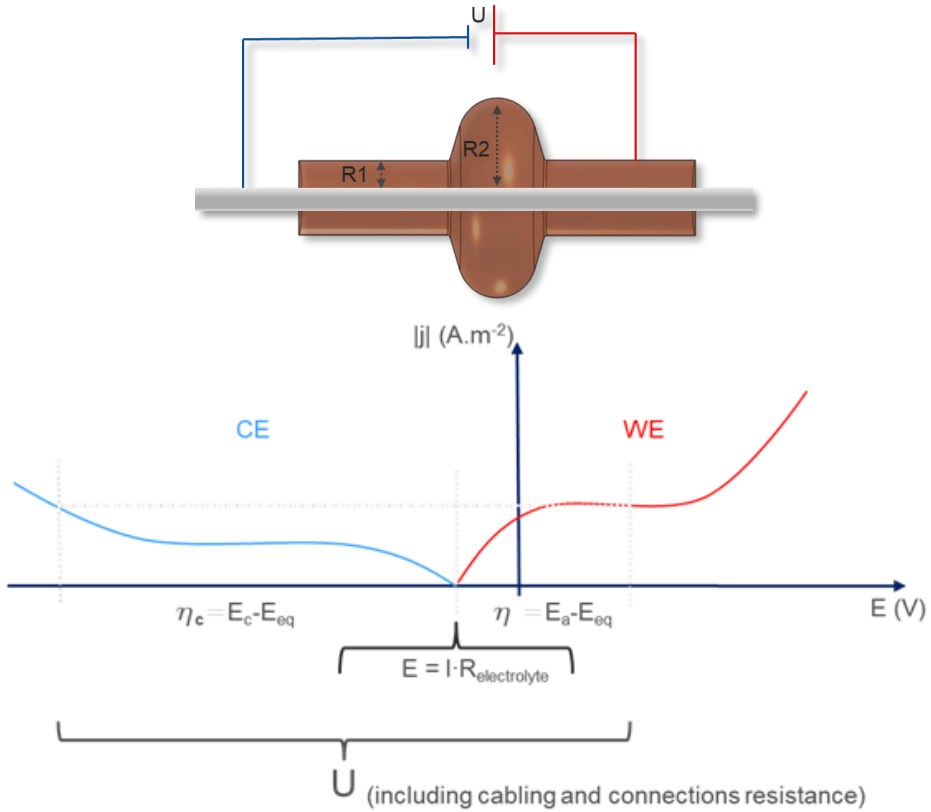


Electropolishing modelling and optimisation

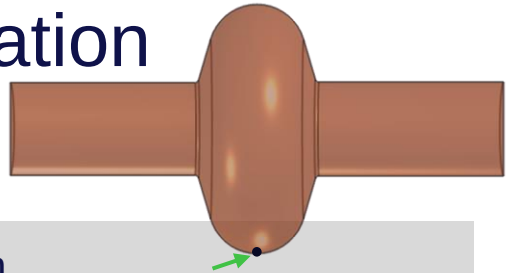
working parameters

$i = f(U, T, v_b, S_c/S_a, \sigma_l, [b])$

- i, Current density
- **U, Overall applied tension**
- **T_b, Bath temperature**
- **v_b, Bath fluid dynamics**
- Sc/Sa, **Cathode geometry** & Cathodic/Anodic surface ratio
- σ_l, Bath conductivity
- [b], Bath composition



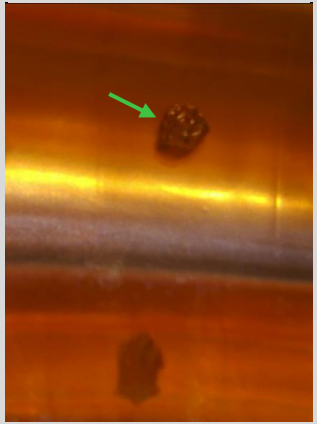
Electropolishing modelling and optimisation



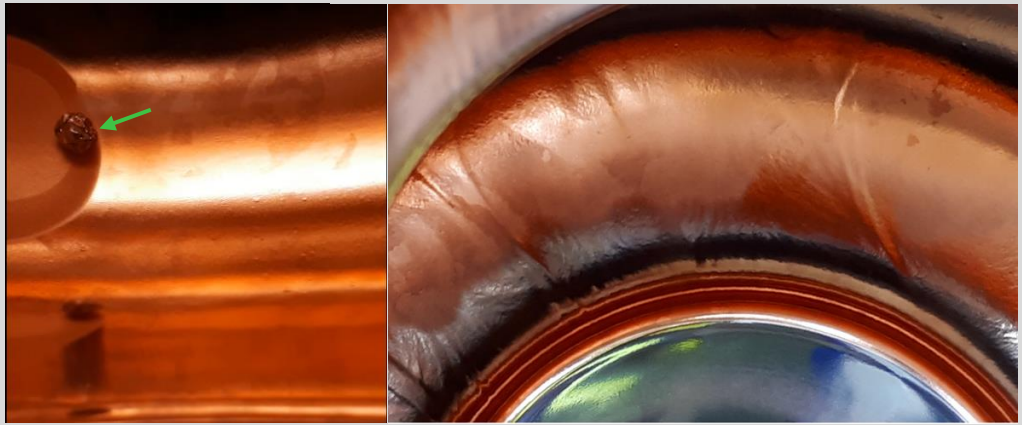
Evidence of fluid dynamics impact on EP

12 V**, 1 rpm**
Horizontal EP

12 V, **0.5 rpm**
Horizontal EP



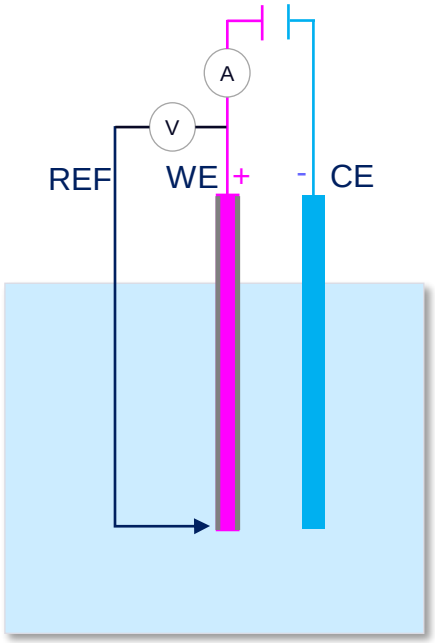
10 V, 0 rpm
Vertical EP



1.3 GHz (N2) cavity on different runs with different working parameters

Electropolishing modelling and optimisation

How to assess fluid dynamics (v_b) and temperature (T) impact on EP?

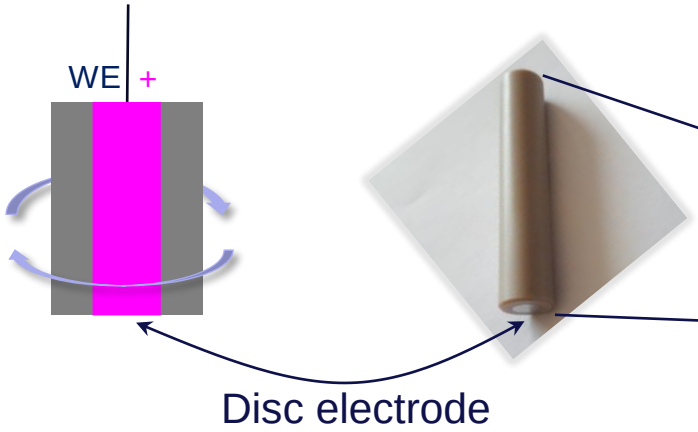


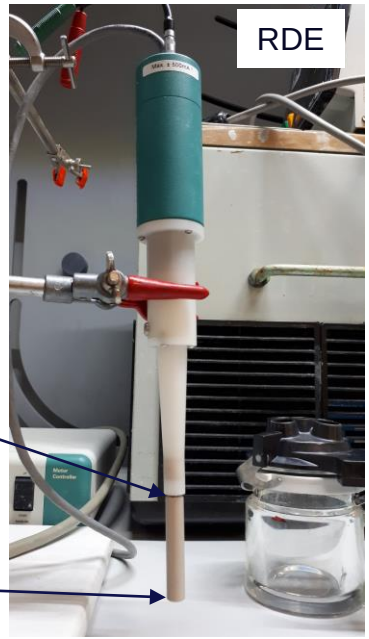
Experimental apparatus:

- Rotating disc electrode (RDE)

Electrochemical methods:

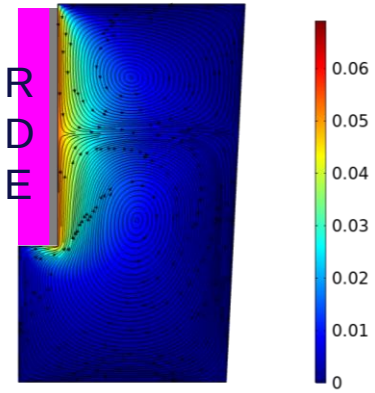
- Voltammetry: $\mathbf{i \propto v_b, T}$.

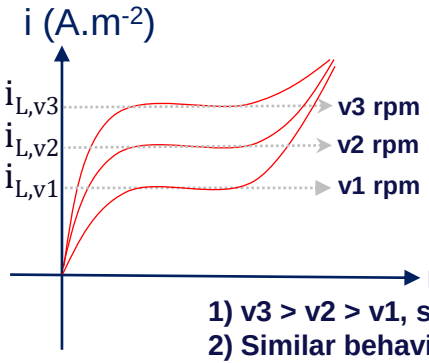




Electropolishing modelling and optimisation

Bath velocity magnitude (m/s)

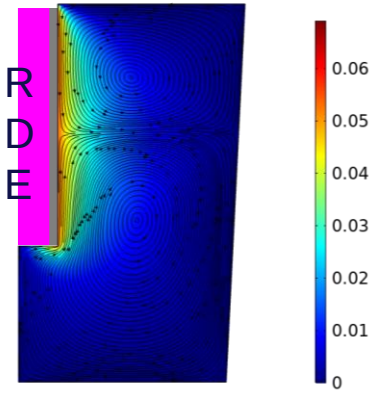


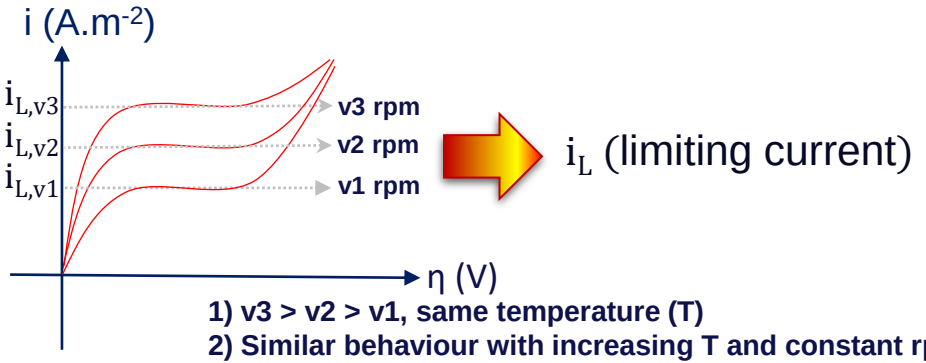


1) v3 > v2 > v1, same temperature (T)
2) Similar behaviour with increasing T and constant rpm

Electropolishing modelling and optimisation

Bath velocity magnitude (m/s)





i_L (limiting current)

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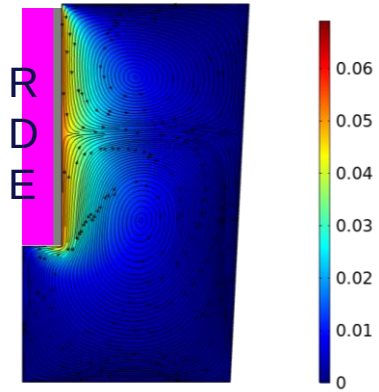
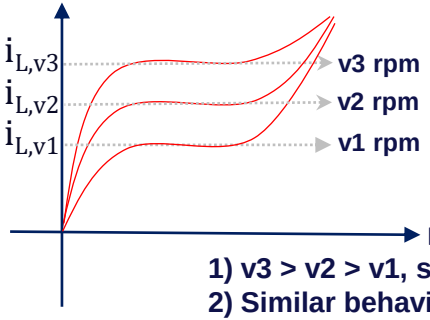
Electropolishing modelling and optimisation

Bath velocity magnitude (m/s)



$$\tau = \sqrt{\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial v}{\partial z}\right)^2}$$

Shear rate (τ) is the rate of change in velocity at which one layer of fluid passes over an adjacent layer



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Electropolishing modelling and optimisation

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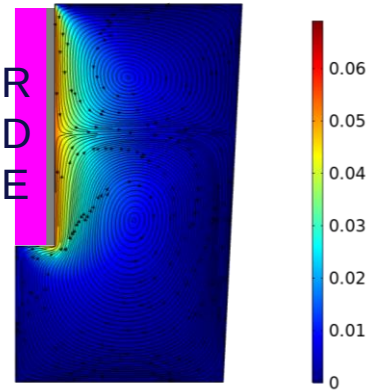

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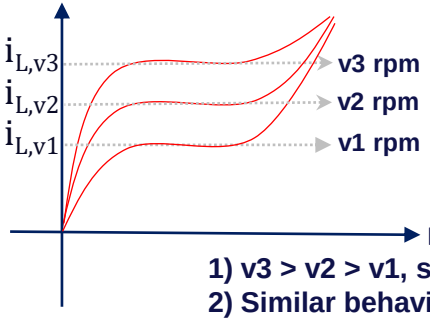

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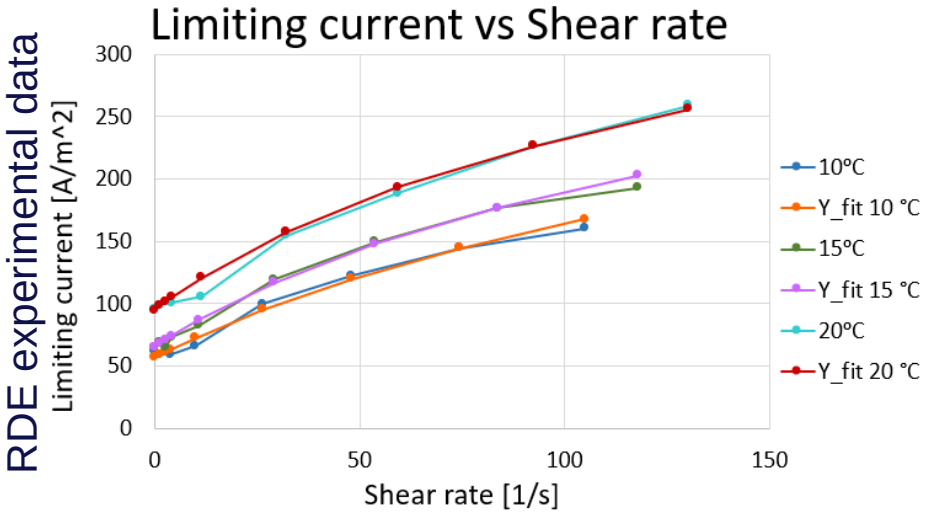
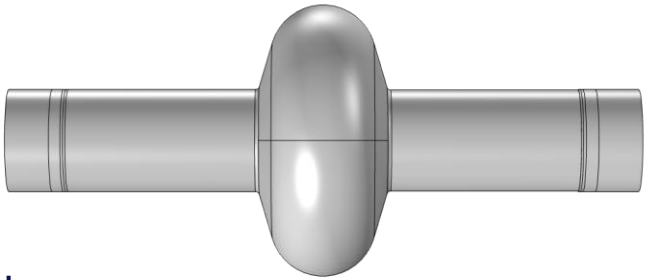
RDE experimental data



RDE model data

Electropolishing modelling and optimisation

Application of: $i = f(\eta)$



1.3GHz
Mass flow rate: 30 L/min
Temperature: 15 °C
0.5 rotations per minute
Overall applied tension: 7.4 V

Electropolishing modelling and optimisation

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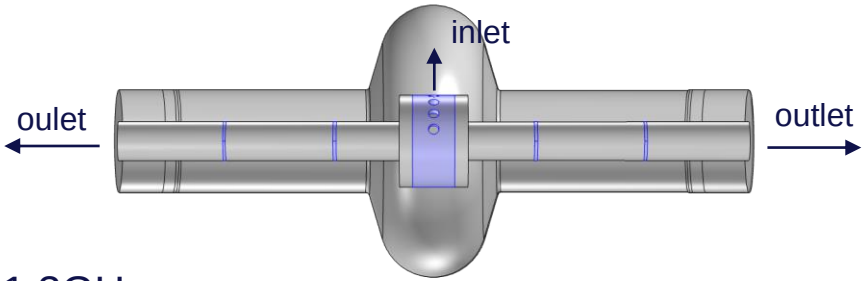

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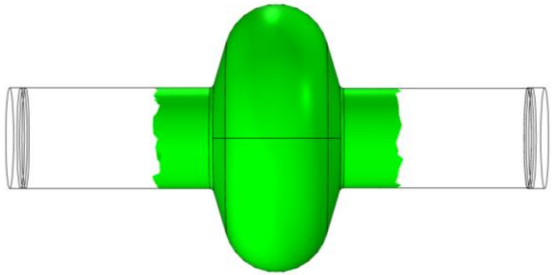

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Electropolished area

Electropolishing modelling and optimisation

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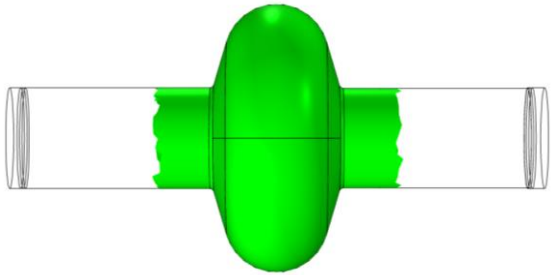

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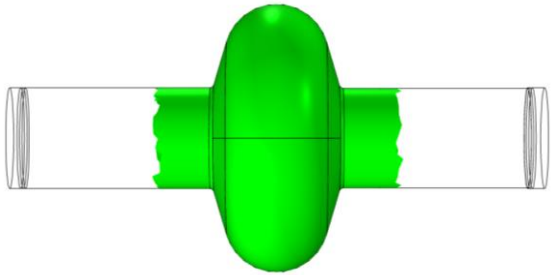
Creation of a new anodic current density function, originated from the results obtained with the RDE:

$$i = f(\eta, \tau)$$

Electropolished area

Electropolishing modelling and optimisation

Application of: $i = f(\eta)$



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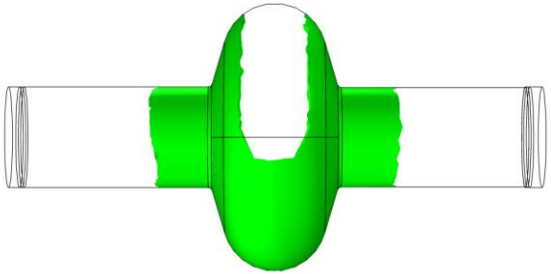
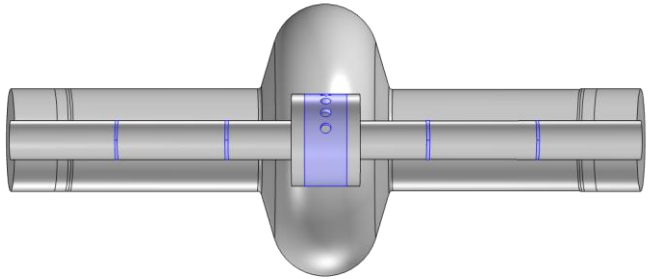


Electropolished area

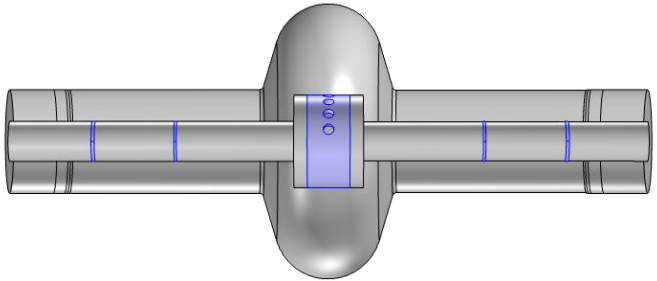
Electropolishing modelling and optimisation

Original 1.3GHz cavity



Mass flow rate: 30 L/min
Temperature: 15 °C
0.5 rotations per minute
Overall applied tension: 7.4 V

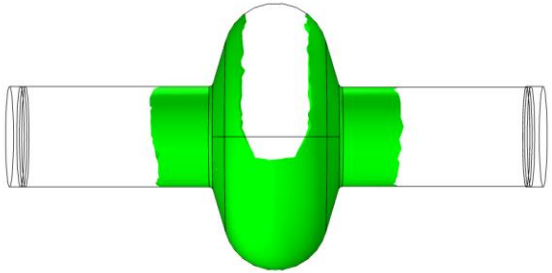
1.3GHz cavity with optimized EP parameters



Mass flow rate: 10 L/min
Temperature: 15 °C
0.5 rotations per minute
Overall applied tension: 10.6 V

Electropolishing modelling and optimisation

Original 1.3GHz cavity



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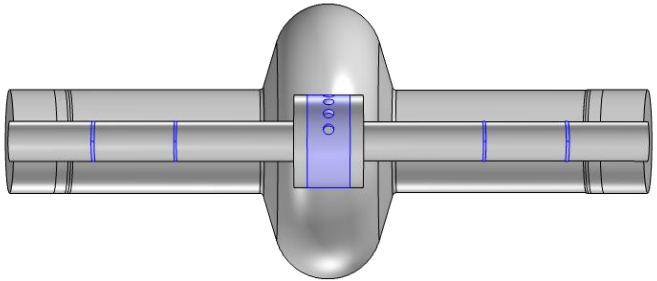
1.3GHz cavity with optimized EP parameters



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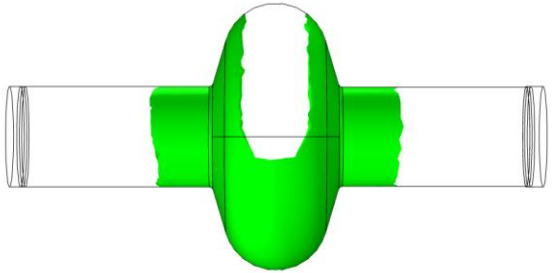
Electropolished area

Electropolishing modelling and optimisation

Original 1.3GHz cavity



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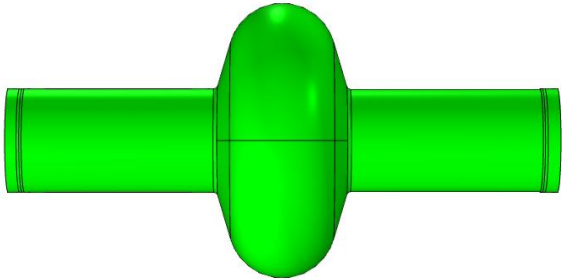
1.3GHz cavity with optimized EP parameters

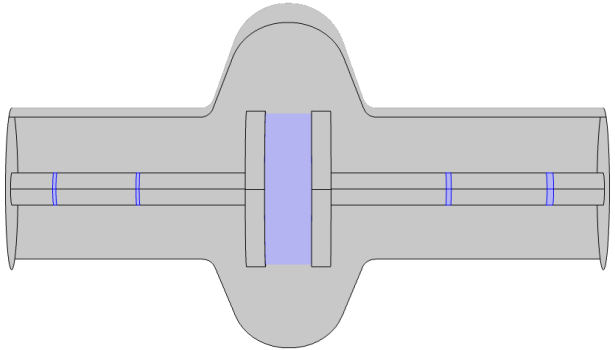


Mass flow rate: 10 L/min
Temperature: 15 °C
0.5 rotations per minute
Overall applied tension: 10.6 V

Electropolished area

Electropolishing modelling and optimisation

Original cathode 400MHz cavity

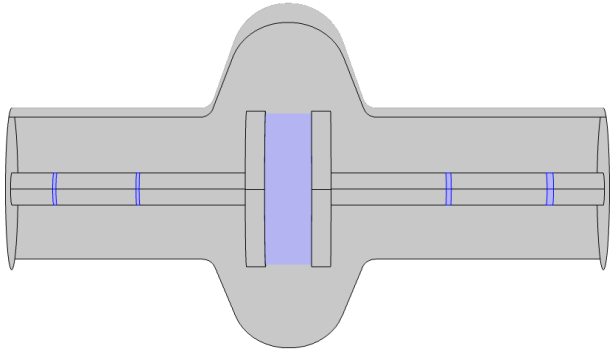


Mass flow rate	30L/min
Overall applied tension	29.5V
Power input	3.6 kW
T_{inlet} - T_{outlet}	2.8 K

Cathode optimisation 400MHz cavity

Electropolishing modelling and optimisation

Original cathode 400MHz cavity



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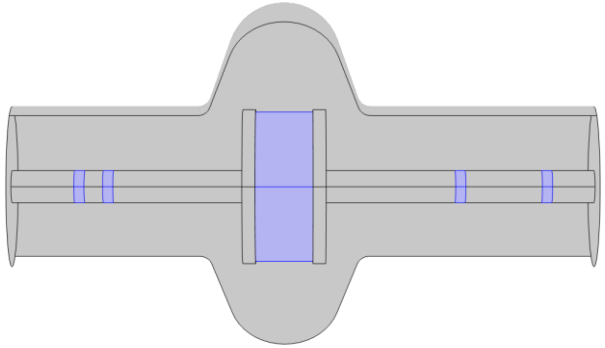
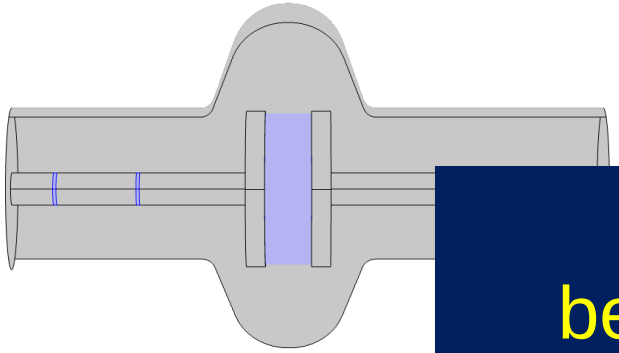
Cathode optimisation 400MHz cavity



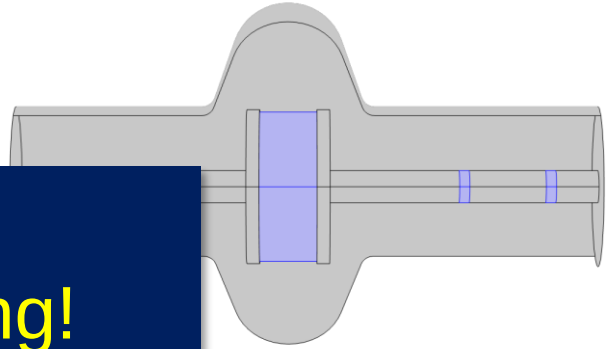
Mass flow rate	30L/min
Overall applied tension	20.5V
Power input	2.2 kW
T_{inlet} - T_{outlet}	1.7 K

Electropolishing modelling and optimisation

Original cathode 400MHz cavity



Cathode optimisation 400MHz cavity

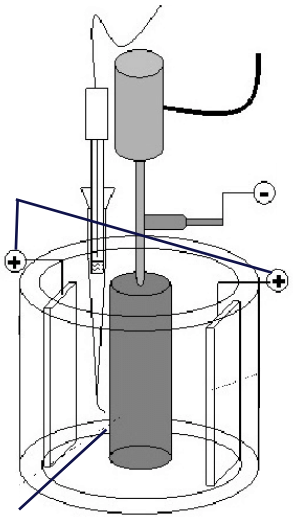


Need of benchmarking!

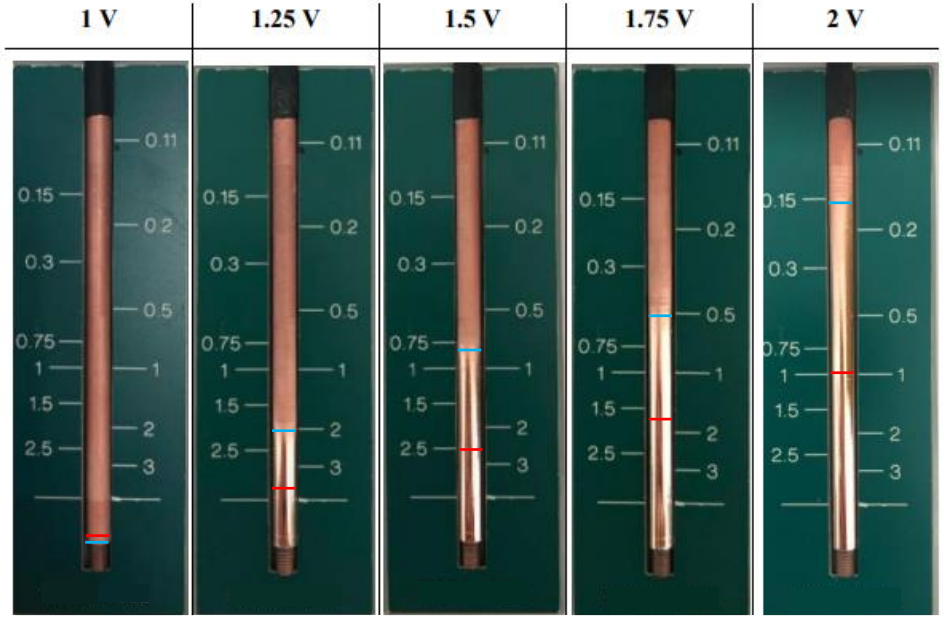
Mass flow rate	30L/min
Overall applied tension	29.5V
Power input	3.6 kW
$T_{inlet} - T_{outlet}$	2.8 K

Mass flow rate	30L/min
Overall applied tension	20.5V
Power input	2.2 kW
$T_{inlet} - T_{outlet}$	1.7 K

Electropolishing modelling and optimisation - benchmarking



Temperature:
10 °C
100 rotations per minute

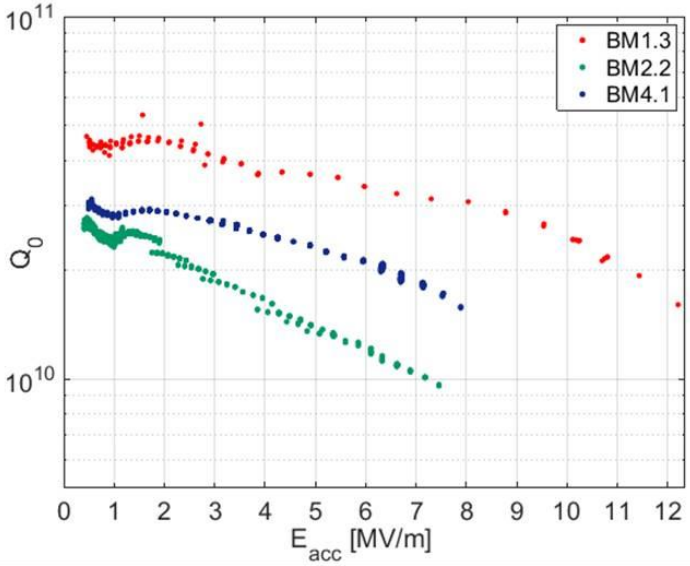


	1 V	1.25 V	1.5 V	1.75 V	2 V
Lab results	0m	0.0218m	0.0365m	0.0441m	0.0539m
Model results	0.003m	0.0106m	0.0181m	0.0252m	0.0319m
$\Delta\eta$	-0.061V	0.063V	0.086V	0.087V	0.09V

Experimental achievements

Electropolishing runs with 1.3 GHz copper cavity

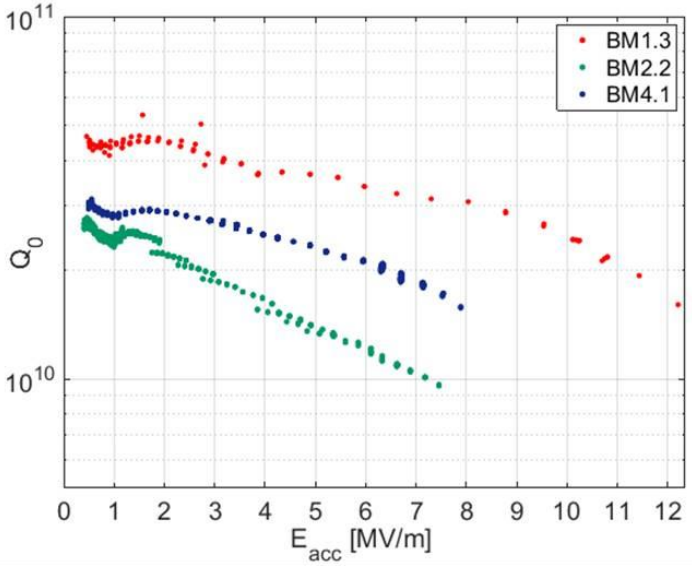
Best results



Experimental achievements

Electropolishing runs with 1.3 GHz copper cavity

Best results



On-going activities:

- Benchmark impact of temperature and fluid dynamics
- Process optimisation (lower power input, uniform EP)

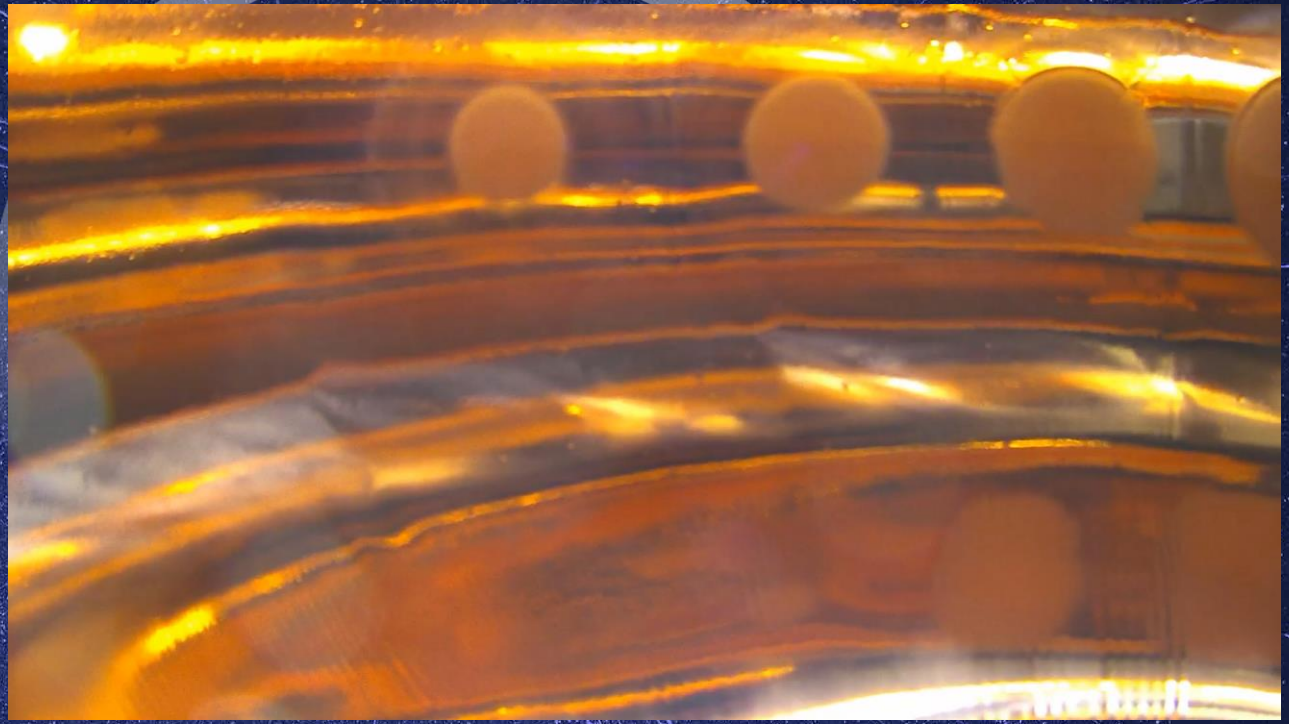
FCC

Thank you for your attention

Thank you for your attention

N2 1.3 GHz cavity inspection after vertical EP trial

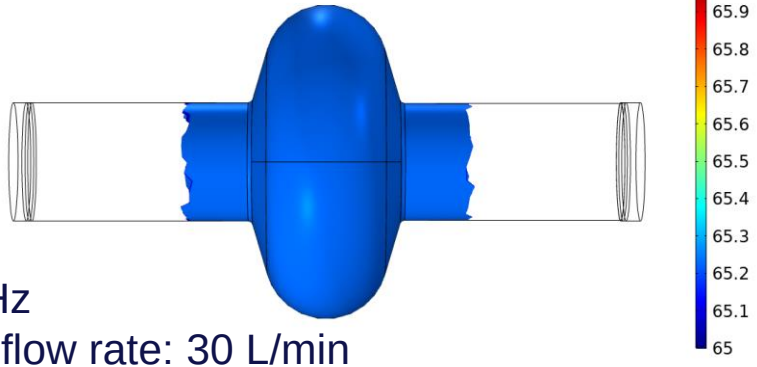
Cathode geometry



Electropolishing modelling and optimisation

Application of: $i = f(\eta)$

Limiting current distribution (A/m²)

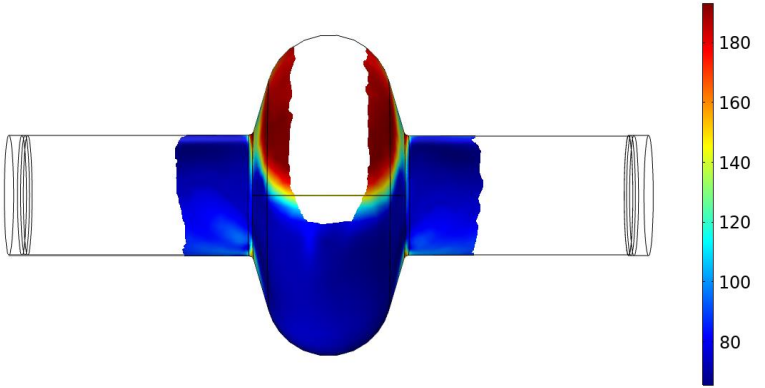


1.3GHz
Mass flow rate: 30 L/min
Temperature: 15 °C
0.5 rotations per minute
Overall applied tension: 7.4 V

Creation of a new anodic current density function, originated from the results obtained with the RDE:

$$i = f(\eta, \tau)$$

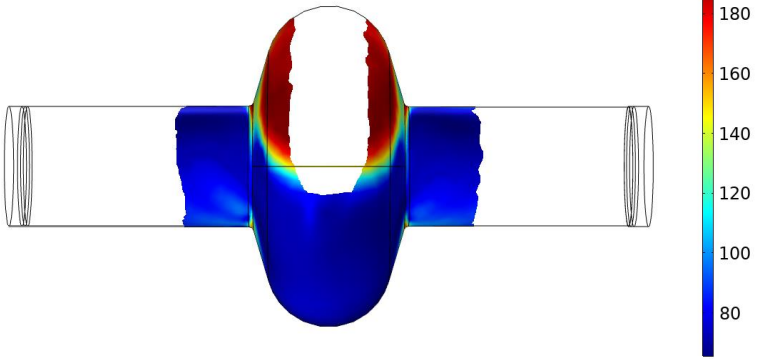
Limiting current distribution (A/m²)



Electropolishing modelling and optimisation

Original 1.3GHz cavity

Limiting current distribution (A/m²)



Mass flow rate: 30 L/min
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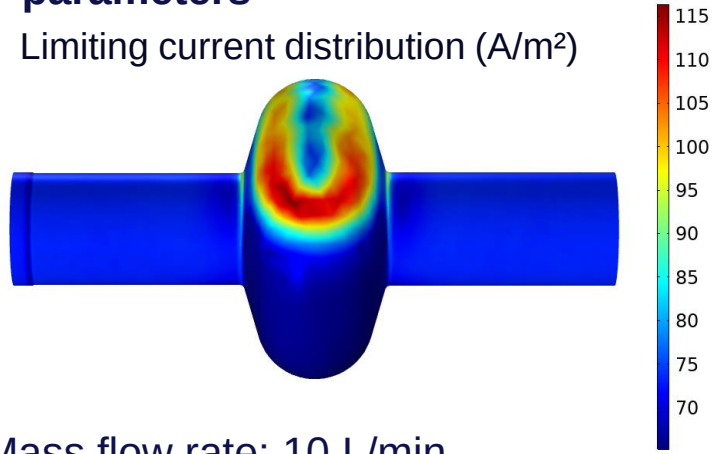
0.5 rotations per minute
Overall applied tension: 7.4 V

1.3GHz cavity with optimized EP parameters

Limiting current distribution (A/m²)



Mass flow rate: 10 L/min
Temperature: 15 °C
0.5 rotations per minute
Overall applied tension: 10.6 V